

CLAIMS

WHAT IS CLAIMED IS:

1. A system for oxygenating blood and delivering the oxygenated blood to a patient,
the system comprising:

a blood pump assembly coupled to a supply of blood;

a blood oxygenation assembly coupled to the blood pump assembly, the blood
oxygenation assembly receiving the blood from the blood pump assembly and oxygenating the
blood, the blood oxygenation assembly comprising a membrane oxygenator comprising:

a housing having a first end portion and a second end portion;

a plurality of tubular membranes disposed in the housing, each of the
plurality of tubular membranes having an internal surface and an external surface;

a first inlet in the housing arranged to deliver oxygen gas into contact with
only the external surface of each of the plurality of tubular membranes;

a second inlet in the housing arranged to deliver the blood into contact
with only the internal surface of each of the plurality of tubular membranes,
wherein the oxygen gas diffuses through the tubular membranes and into the
blood to form the oxygenated blood; and

an outlet in the housing for expelling the oxygenated blood; and

a delivery assembly coupled to the outlet, the delivery assembly being adapted to deliver
5 the oxygenated blood to a patient.

2. A system for oxygenating blood and delivering the oxygenated blood to a patient,
the system comprising:

10 a blood pump assembly coupled to a supply of blood;

a blood oxygenation assembly coupled to the blood pump assembly, the blood
oxygenation assembly receiving the blood from the blood pump assembly and oxygenating the
15 blood, the blood oxygenation assembly comprising a membrane oxygenator comprising:

a housing having a first end portion, a second end portion, and an oxygen
gas inlet port;

20 a plurality of hollow fibers disposed within the housing, the plurality of
hollow fibers generally extending between the first end portion and the second
end portion of the housing, the plurality of hollow fibers being adapted to pass
fluid from the first end portion of the housing to the second end portion of the

housing while permitting oxygen gas diffusion therethrough;

5 a first seal disposed about the plurality of hollow fibers in the first end portion of the housing and a second seal disposed about the plurality of hollow fibers in the second end portion of the housing, the first and the second seal defining therebetween a gas chamber within the housing, the gas chamber being coupled to the oxygen gas inlet port;

10 a first end cap disposed on the first end portion of the housing, the first end cap having a blood inlet port and defining a blood inlet manifold between the first end cap and the first seal; and

15 a second end cap disposed on the second end portion of the housing, the second end cap having a blood outlet port and defining a blood outlet manifold between the second end cap and the second seal; and

a delivery assembly coupled to the blood outlet port, the delivery assembly being adapted to deliver the oxygenated blood to a patient.

20 3. A device for oxygenating blood and delivering the oxygenated blood to a patient, the system comprising:

a blood pump assembly coupled to a supply of blood;

a blood oxygenation assembly coupled to the blood pump assembly, the blood oxygenation assembly receiving the blood from the blood pump assembly and oxygenating the blood, the blood oxygenation assembly comprising:

a mixer having an internal mixing chamber having a first inlet, a second inlet, and an outlet, the blood pump adapted to deliver the blood to the mixing chamber of the mixer via the first inlet; and

a fluid supply assembly adapted to deliver a gas-supersaturated physiologic fluid to the mixing chamber of the mixer via the second inlet, the blood and the physiologic fluid mixing with one another to form the oxygenated blood; and

a delivery assembly coupled to the outlet, the delivery assembly being adapted to deliver the oxygenated blood to a patient.

4. The device, as set forth in claim 3, wherein the physiologic fluid comprises saline.
5. The device, as set forth in claim 3, wherein the oxygenated blood is hyperoxic.
6. The device, as set forth in claim 3, wherein the oxygenated blood is hyperbaric.

7. The device, as set forth in claim 3, wherein the first inlet is arranged to create a vortical flow in the mixing chamber.

8. The device, as set forth in claim 3, wherein the mixing chamber is pressurizable.

9. The device, as set forth in claim 3, comprising a control assembly coupled to the blood pump.

10. The device, as set forth in claim 9, comprising a display coupled to the control assembly.

11. The device, as set forth in claim 3, wherein the blood pump receives the blood from the patient.

12. The device, as set forth in claim 3, wherein the mixing chamber comprises a substantially cylindrical wall and wherein the first inlet is arranged to direct fluid along a path substantially tangential to the cylindrical wall.

13. A device for oxygenating blood and delivering the oxygenated blood to a patient, the system comprising:

a blood pump assembly coupled to a supply of blood;

a blood oxygenation assembly coupled to the blood pump assembly, the blood oxygenation assembly receiving the blood from the blood pump assembly and oxygenating the blood, the blood oxygenation assembly comprising:

an oxygenator having a first inlet, a second inlet, and an outlet, the blood pump adapted to deliver the blood to first inlet of the oxygenator; and

a gas-fluid supply assembly comprising:

a fluid supply;

a chamber having a first inlet, a second inlet, and an outlet;

a pump coupled to receive fluid from the fluid supply and to deliver the fluid to the first inlet of the chamber;

an oxygen gas supply coupled to deliver oxygen gas to the second inlet of the chamber, the oxygen gas supply maintaining pressure within the chamber at a predetermined level; and

an atomizer nozzle coupled to the first inlet of the chamber, the atomizer nozzle creating a droplet pattern of the fluid in the oxygen gas

within the chamber to diffuse the oxygen gas into the fluid to create an oxygen-supersaturated fluid, the oxygen-supersaturated fluid collecting within the chamber below the atomizer nozzle and being removable from the chamber via the outlet of the chamber, the outlet of the chamber being coupled to the second inlet of the oxygenator to deliver the gas-supersaturated fluid into contact with the blood to form the oxygenated blood; and

a delivery assembly coupled to the outlet of the oxygenator, the delivery assembly being adapted to deliver the oxygenated blood to a patient.

14. The device, as set forth in claim 13, wherein the fluid from the fluid supply comprises physiologic fluid.

15. The device, as set forth in claim 14, wherein the physiologic fluid comprises saline.

16. The device, as set forth in claim 13, wherein the droplet pattern comprises a cone.

17. The device, as set forth in claim 16, wherein the cone has an angle of about 20 degrees.

18. The device, as set forth in claim 13, wherein the oxygen-supersaturated fluid has a dissolved gas content that would occupy a volume of between about 0.5 and about 3.0 times the volume of the fluid from the fluid supply normalized to standard temperature and pressure.

5 19. The device, as set forth in claim 14, comprising a second pump coupled to the outlet of the chamber to remove the gas-supersaturated fluid from the chamber.

20. A device for oxygenating blood and delivering the oxygenated blood to a patient, the system comprising:

0 a blood pump assembly coupled to a supply of blood;

a blood oxygenation assembly coupled to the blood pump assembly, the blood oxygenation assembly receiving the blood from the blood pump assembly and oxygenating the blood, the blood oxygenation assembly comprising:

5 an oxygenator having a first inlet, a second inlet, and an outlet, the blood pump adapted to deliver the blood to first inlet of the oxygenator; and

0 a gas-supersaturated fluid supply assembly comprising:

a fluid supply;

a chamber having a first inlet, a second inlet, a third inlet and an outlet;

a gas supply coupled to deliver gas to the first inlet of the chamber;

a piston assembly coupled to receive fluid from the fluid supply and to deliver the fluid to the second inlet and the third inlet of the chamber;

a nozzle coupled to the third inlet of the chamber, the nozzle delivering the fluid from the piston assembly to the chamber;

a first valve coupled to the outlet of the chamber, the first valve being coupled to an actuator assembly to control delivery of gas-supersaturated fluid from the chamber, the outlet of the chamber being coupled to the second inlet of the oxygenator to deliver the oxygen-supersaturated fluid into contact with the blood to form the oxygenated blood; and

a second valve coupled to the second inlet, the second valve being coupled to an actuator assembly to control dilution during the creation of gas-supersaturated fluid within the chamber; and

a delivery assembly coupled to the outlet of the oxygenator, the delivery assembly being adapted to deliver the oxygenated blood to a patient.

5 21. The device, as set forth in claim 20, wherein the piston assembly maintains fluid pressure within the chamber at a predetermined level.

 22. The device, as set forth in claim 20, wherein the predetermined level is at least 500 psi.

10 23. The device, as set forth in claim 20, wherein the fluid from the fluid supply comprises physiologic fluid.

 24. The device, as set forth in claim 23, wherein the physiologic fluid comprises saline.

 25. The device, as set forth in claim 20, wherein the piston assembly comprises a syringe having a piston, and further comprising a motor coupled to the piston of the syringe to pressurize fluid from the fluid supply prior to delivery of the fluid to the first inlet of the chamber.

20 26. The device, as set forth in claim 20, wherein the second valve is closed to facilitate atomization of the fluid through the nozzle.

27. The device, as set forth in claim 20, wherein the second valve is open to facilitate fluid dilution.

5 28. The device, as set forth in claim 20, wherein the actuator assembly adjusts the first valve to control removal of the gas-supersaturated fluid from the chamber.

29. The device, as set forth in claim 20, comprising a control assembly coupled to the actuator assembly.

0 30. The device, as set forth in claim 29, comprising a display coupled to the control assembly.

5 31. The device, as set forth in claim 20, wherein the piston assembly delivers the fluid to the third inlet of the chamber continuously.

32. The device, as set forth in claim 20, wherein the piston assembly delivers the fluid to the third inlet of the chamber intermittently.

33. The device, as set forth in claim 20, comprising a first check valve coupled between the piston assembly and the chamber to prevent fluid loss from the chamber during delivery of fluid from the fluid supply to the piston assembly.

34. The device, as set forth in claim 33, comprising a second check valve coupled between the piston assembly and the fluid supply to prevent fluid flow to the fluid supply during delivery of fluid to the chamber by the piston assembly.

5 35. The device, as set forth in claim 34, comprising a third check valve coupled to the nozzle to prevent fluid and gas flow from the chamber through the nozzle.

10 36. The device, as set forth in claim 20, wherein the actuator assembly comprises a first solenoid coupled to the first valve, a second solenoid coupled to the second valve, and a third solenoid coupled to the third valve, each respective solenoid being adapted to move its respective valve between an opened position and a closed position.

5 37. The device, as set forth in claim 20, wherein the chamber comprises a disposable housing coupled to a cap.

0 38. The device, as set forth in claim 20, comprising a protective housing assembly disposed about the chamber.